Study on soldering flux used for Sn-0.7Cu welding wire

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Abstract

The wettability and corrosiveness of some organic acids were tested to choose an appropriate activator. Then orthogonal design method was used to determine the proportion among the components of the activator. At last a certain amount of water-white rosin was added to further optimize the dispensation. The final soldering flux for Sn-0.7Cu welding wire caters to the demands of welding process such as good weld ability, good liquidity, less smoke, full and shiny welding spot.

Introduction

While traditional Sn-Pb solder has been widely used in packaging and joining process in modern electronic packaging based on its advantages of good wettability, low melting point, abundant reserves, low prize and so on, But one of the components Pb is harmful to human beings' health and living environment. In recent years, more and more governments and organizations pay more attention on health and environment problem and appeal lead-free process in welding system. WEEE(Waste Electrical and Electronic Equipment) leaded by European Union required to eliminate materials containing Pb in electronic packaging industry before 2006, and most of countries are trying their best to develop lead-free solders--substitute of the Sn-Pb solder [1~3]. As an important industrial country, China has experienced a rapid development in electronic industry, and we can not image that if we have not electronic products in my life. Then China must also advocate lead-free solders in order to become an advanced industrial country.

So far, all lead-free solders are based on Sn, then one or several other elements are added among Bi、In、Zn、Au、Ti、Cu、Sb and Ag to acquire the suitable melting point and mechanical properties [4,5]. Among these lead-free solders, Sn-0.7Cu alloy is a potential one which can be widely used in electronic packaging due to its low cost and outstanding property, and the component Cu in solder can adjust the thickness of intermetallic compound (IMC) by inhibiting the over-diffusion of substrate Cu to solder alloys. The melting point of Sn-0.7Cu is 227 ℃ which is higher than that of Sn-37Pb—183 ℃ that is showed in Sn-Cu and Sn-Pb phase diagram, but it is still conformable in industry. Because of the good wettability of congruent melting Sn-Cu on substrate Cu, Vincent et al [6] believe this alloy could have a great applied potentiality. And now Sn-Cu solder has been produced in batch in China.

Although Sn-Cu alloy has a great potential in lead-free-welding, it still exists some disadvantages. The Sn-0.7Cu welding wire which is made of Sn-Cu alloy and rosin-based soldering flux exists defeats of strong fume, poor fluidity and so on. The purpose of this paper is to develop a soldering flux for Sn-0.7Cu welding wire to solve the problems occurred during the lead-free welding process.

Experimental procedures

Sn-0.7 Cu welding wire alloys were prepared in the experiments. Six pieces of 25mm×25mm×0.3mm copper were cut, polished, and dipped in 3% wt HCl solution and 5% wt NaOH solution for 10 seconds , respectively then cleaned by absolute ethyl alcohol before being placed in the KRUSS DSA-100 instrument, 10 wt% active solutions of succinic acid, adipic acid, sebacic acid, tartaric acid, citric acid and triethanolamine were prepared, respectively.

Firstly, wettability test would be made. The temperature of KRUSS DSA-100 instrument was set at 250 ℃. Six portions of welding wire of 0.200±0.005g with no flux were cut and laid on the

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Table 1. Orthogonal array(A, B, C, D are OP-10, Succinic acid, Adipic acid and Triethanolamine respectively)

Factors / NO.	(1)A	(2)B	(3)C	(4)D	Spreading area(mm^2)
1	0.1%	2%	2%	1%	43.0003
2	0.1%	6%	3%	2%	43.6099
3	0.1%	7%	4%	3%	41.2521
4	0.1%	2%	3%	3%	39.3623
5	0.1%	6%	4%	1%	42.0805
6	0.1%	7%	2%	2%	41.6105
7	0.2%	2%	4%	2%	42.2964
8	0.2%	6%	2%	3%	43.4087
9	0.2%	7%	3%	1%	40.2464
K_1	250.9155	124.6590	128.0195	125.3272	
K_2	125.9515	129.0991	123.2186	127.5168	
K_3		123.1090	125.6290	124.0231	
k_1	41.8192	41.5530	42.6732	41.7757	
k_2	41.9838	43.0330	41.0729	42.5056	
k_3		41.0363	41.8763	41.3410	
R	0.1646	1.9967	1.6003	1.1646	
Optimized level	A_2	B_2	C_1	D_2	
Effect of factors	BCDA				
Optimized dispensation	$B_2C_1D_2A_2$				

center of copper pieces ,respectively. When the temperature of instrument was kept at 250 ℃, the six kinds of prepared active solutions were orderly dropped about 0.002g on the welding wire. Then the copper pieces were put into KRUSS DSA-100 to weld for about 90 seconds. At last, the welding spots would be taken photos and then imported photos into Auto CAD software to calculate the spreading area. Secondly, corrosiveness test would be made, the six kinds of active solutions were dropped two drops onto the copper pieces which have been prepared ,and then let them flow on the copper pieces naturally. After that, the copper pieces were put into drying oven at 80℃ for 2 hours and then observed the color of copper, respectively. At last, the copper pieces were put into drying oven at 40℃ for 72 hours again, and observed the color of them.

It should adjust the proportion among the components of the activator after the components were confirmed. The orthogonal design method would be used, the factors contained succinic acid, adipic acid, triethanolamine and OP-10 which is used as surface active agent to improve wettability of flux. Succinic acid contained three levels of 2%，6%，7%, adipic acid contained three levels of 2%，3%，4%, triethanolamine contained three levels of 1%，2%，3% and OP-10 contained two levels of 0.1%, 0.2%. Then orthogonal array of $L_9(2^1 \times 3^3)$ was chosen. There were nine group experiments in this orthogonal design and showed in table 1.

Results and discussions

The ability of removing oxide film of the Cu substrate is different for various activators, which would greatly affect the performance of welding. This ability is judged by the spreading area of welding spot. When the area is larger, the performance is better. Meanwhile, the activator of the soldering flux is acid, which could corrode the Cu substrate at high temperature. When the acidity is stronger, the corrosiveness is stronger. So we should consider thoroughly to avoid caring for this and losing that.

Table 2. The spreading area and corrosiveness of welding spots using different activators

Activator	Succinic acid	Citric acid	Adipic acid	Triethanolamine	Tartaric acid	Sebacic acid
Spreading area（mm^2）	42.0111	42.6303	50.8639	39.7781	34.8992	41.3773
Surface of welding point（72h）	No change	Black	Dark	No change	Light black	Green stains

Table.2 shows the spreading area and corrosiveness of Sn-0.7Cu wire welding spots using different activators. Fig.1&2 reflect the macro-pictures of welding sports. The spreading area of using adipic acid was the largest, extending to 50.8639mm^2, but corrosiveness to substrate was lightly serious, so adipic acid can not be used independently. The spreading area of using succinic acid, citric acid and sebacic acid were nearly the same, and the corrosiveness to substrate of the last one was serious while that of succinic acid was very light. So succinic acid may be a potential one. The spreading area of using triethanolamine was close to 40mm^2, and triethanolamine is also a alkaline matter which can reduce the corrosiveness when it was used as activator with other active acids. The spreading area of using tartaric acid was small, and also its corrosiveness was serious. So tartaric acid is not fit for being activator. At last, the preliminary dispensation was confirmed according to above analysis: succinic acid was the prime component of activator, adding a little of adipic acid and triethanolamine as modifier to improve wettability and reduce corrosiveness.

There were nine group experiments in this orthogonal design, and their results of dispensation and spreading area were showed in Table 1. Because of $R_B > R_C > R_D > R_A$, the effect of different factors on welding spot was: B（Succinic acid）> C（Adipic acid）> D（Triethanolamine）>A（OP-10）. With regard to A, k2＞k1, then A_2 was its best level. With regard to B, k2＞k1＞k3, then B_2 was its best level. With regard to C, k1＞k3＞k2, then C_1 was its best level. And with regard to D, k2＞k1＞k3, then D_2 was its best level. So the optimized dispensation was $B_2C_1D_2A_2$, that was: Succinic acid 6%,Adipic acid 2%， Triethanolamine 2%,OP-10 0.2%.The result of this dispensation was not contained in Table 1, so we must through experiment to verify that if it is better than all dispensation in Table 1. And the result of experiment showed that the spreading area of welding spot using this dispensation was 44.6493mm^2 which is superior to all results in Table 1. So this optimized dispensation is suit to our requirements.

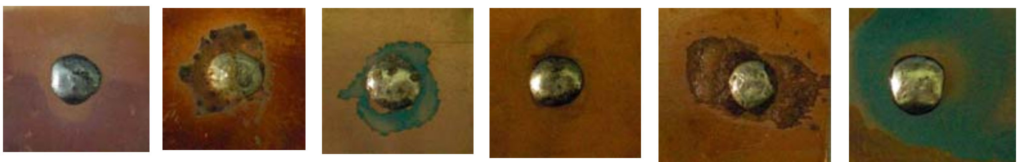

Fig.1 The macro-pictures of Sn-0.7Cu wire welding spots using different activators before cleaning (from left to right: using Succinic acid, Citric acid, Adipic acid, Triethanolamine, Tartaric acid and Sebacic acid)

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Fig.2 The macro-pictures of Sn-0.7Cu wire welding spots using different activators after cleaning (from left to right: using Succinic acid, Citric acid, Adipic acid, Triethanolamine, Tartaric acid and Sebacic acid)

To further improving the wettability of Sn-0.7Cu welding wire, a certain amount of water-white rosin was added to the optimized dispensation to make up the final flux. Two schemes were experimented: 1, adding 10% water-white rosin & 2, adding 15% water-white rosin to make up the final flux which is used for Sn-0.7Cu welding wire. The result was showed in Fig.3 that the spreading area of scheme 1 was $45.4802mm^2$ while that of scheme 2 was $47.5792mm^2$,so scheme 2 is better, and there were nearly no fume during welding process, only a little residue after welding, the welding spot was full and shiny, the fluidity also is good. So the optimized dispensation was: succinic acid 6%， adipic acid 2%， triethanolamine 2%， OP-10 0.2%, water-white rosin 15%.

Conclusions

The wettability and corrosiveness of some organic acids were tested, the results showed: the wettability of succinic acid was good, and there was nearly no corrosiveness to Cu substrate. It can be used as the main component of activator. Triethanolamine is a alkaline matter and used as modifier in activator. Orthogonal design was used to optimize the main components of flux. And the optimized dispensation was: succinic acid 6%， adipic acid 2%， triethanolamine 2%， OP-10 0.2%, water-white rosin 15%. The final soldering flux for Sn-0.7Cu welding wire has good property such as good weld ability, good liquidity, less smoke, full and shiny welding spot.

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